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PATENT & TRADEMARK OFFICE

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: S. Ben Choi	Group Art Unit: 2863
Serial No.: 10/719,968	Confirmation No.: 3571
Filed: 11/21/2003	Examiner: Sun, Xiuqin
For: Vehicle Anti-Rollover Monitor Using Kinetic Energy and Lateral Acceleration	Attorney Docket: 1-24440

DECLARATION UNDER 37 CFR 1.131

I, S. Ben Choi, hereby declare that:

1. I am the inventor of all claims of the patent application identified above and of the subject matter described therein.

2. I am aware of U.S. patent 6,856,868 to Le et. al. dated February 15, 2005, (with an original filing date of October 24, 2003) that is being used as a basis for a rejection of the above patent application by the U.S. Patent and Trademark Office.

3. Prior to October 24, 2003, we had completed our invention as described and claimed in the subject application in the United States, as evidenced by the following.

4. Prior to October 24, 2003, we reported our invention within the Kelsey Hayes (TRW) invention disclosure system as Invention Disclosure number 011884-00. The form and the main text of the disclosure is submitted herewith as Exhibit #1. A written description and drawings of the invention by the inventor is also submitted herewith as Exhibit #2 establishing a date prior to the invention's submission into the Kelsey-Hayes (TRW) invention disclosure system. The inventive concepts covered by the claims in the subject application are described throughout Exhibit #1 and #2 and both pre-date the original filing date of October 24, 2003.

5. Prior to October 24, 2003, we reduced to practice our claimed invention by means of computer simulation, the results of which are shown in exhibit #1. The simulation was modeled using MATLAB and CarSim. Pages 3-5 of Exhibit #1 show successful results wherein the roll over index was accurately correlated with the roll over propensity for the two different steering maneuvers.

6. Each of the dates deleted from Exhibits #1-#2 are prior to October 24, 2003.

7. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that the statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application identified above or any patent issued thereon.

May-31-2005

S. Ben Choi   Date

Exhibit #1

Kelsey-Hayes 1-24440

TRW

CONFIDENTIAL AND PRIVILEGED

TRW FILE NO. 011884-00 / LSA

INVENTION DISCLOSURE FORM

DIRECTIONS

1. This form should be completed for any proposed new TRW product, algorithm, process or machine you believe may be an invention.
2. Complete this form as soon as possible after you have thought of your invention -- it is not necessary for the invention to have been prototyped or tested.
2. Attach any related drawings or other written material to this form.
3. This form should be reviewed, signed and dated by each inventor and a witness.
4. When completed, forward this form with any attachments to TRW's Patent Counsel, at the address shown on back.

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1. Title of the invention : Vehicle Roll Over ~~Estimation Using Only Yaw Stability Control Sensors~~

2. Date conceived (when the invention was first thought of) : [redacted]

3. Date of first sketch, written description, or drawing of the invention (Please attach copies) : [redacted]

4. Date first disclosed to anyone : [redacted]
   To whom? Arnie Spieker

5. Please state what features of the invention you consider to be new, and how the invention improves over previously known products or processes.

   In this invention, the roll over propensity of a vehicle is estimated without using roll angle or roll rate sensor. The roll over index is defined using the vehicle lateral kinetic energy and the vehicle lateral acceleration which is measured by a accelerometer attached on the vehicle sprung mass

6. Please attach sketches, drawings, flowcharts, memos or other descriptive material which illustrates or describes the present preferred and alternate versions of the invention. Please list below all materials which you have attached.

   One descriptive material is attached

7. Provide the following information for each person who is believed to be an inventor and have each inventor and one witness, who understands the invention, sign and date at the appropriate places. Signatures are not required for listed inventors who are not TRW employees.

INVENTOR: S. Ben Choi

Home Address: 2384 Hickory Point Drive, Ann Arbor, MI 48105

"Exhibit #1

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Business Tel. 734-266-1532   Business Fax 734 266 1671

Signature of Inventor ______________ Date: [redacted]

WITNESSED AND UNDERSTOOD BY: Danny Milot
Typed or Printed Name

Signature of Witness Danny Milot Date: [redacted]

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One Maritime Plaza, Fourth Floor
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Exhibit #1

KELSEY-HAYES (49)

1-24440

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Vehicle Roll Over Estimation Using Only Yaw Stability Control sensors

1. General Description

The roll over of the high C.G. vehicle is a very critical issue of the vehicle safety. There have been many studies to estimate the roll over propensity by measuring or estimating the vehicle roll angle. In this document, an indirect roll over estimation method is suggested. The suggested method predicts the propensity of vehicle roll over by monitoring the lateral kinetic energy and the lateral acceleration of a vehicle. The lateral kinetic energy is calculated through the vehicle longitudinal velocity and the vehicle side slip angle which is estimated using yaw stability control sensors. This method predicts the roll over propensity fairly accurately without a roll angle or a roll rate sensor.

2. Roll Over Estimation Algorithm

Figure 1 shows the diagram of the front view of a vehicle where y and z axes are fixed to the vehicle sprung mass C.G. and rotate with the mass. a_{ym} is the lateral acceleration measured by an accelerometer attached to the vehicle sprung mass. The measured acceleration is partly the vehicle acceleration and partly the gravity term. φ is the roll angle of the vehicle sprung mass due to the lateral acceleration and/or the super elevation angle of the road surface.

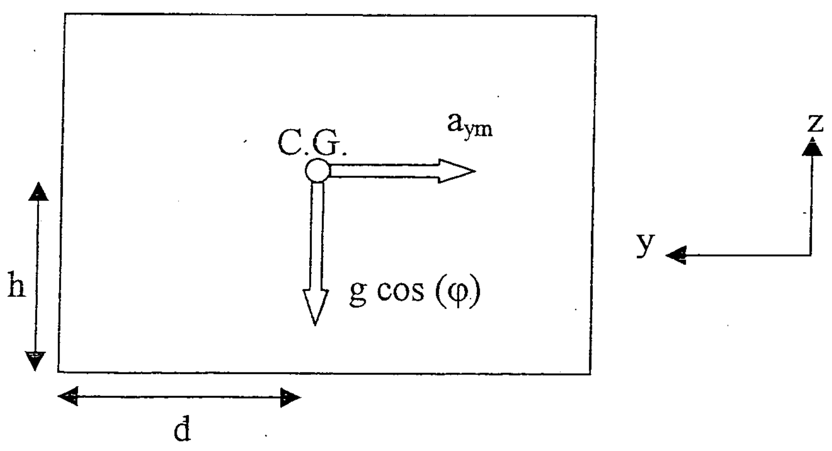

Figure 1. Diagram of vehicle coordination

If θ is defined as follows from a_{ym} and g cos(φ):

$$\tan\theta \equiv \frac{a_{ym}}{g\cos\varphi}$$

Then, the diagram in Figure 1 can be reconfigured as Figure 2.

Exhibit #1.

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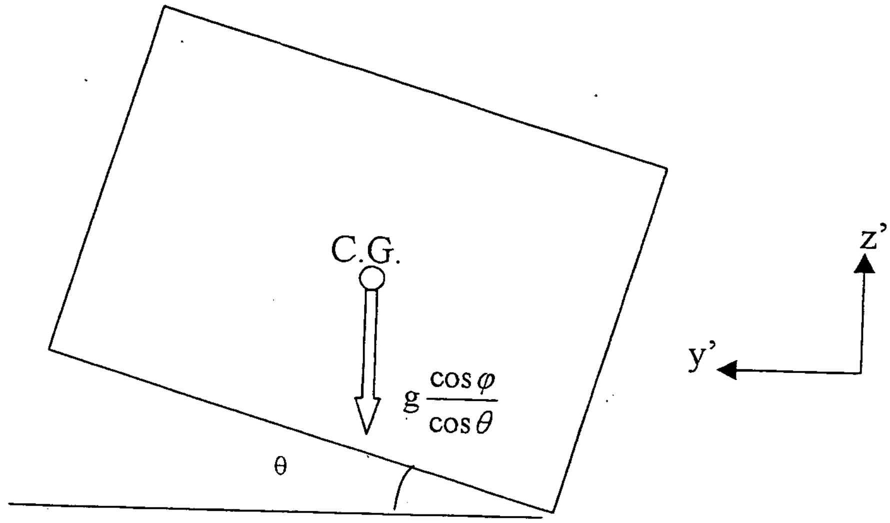

Figure 2. Diagram of a vehicle in virtual gravity coordinates

In the reconfigured coordinates, z' axis is parallel to the direction of the net force on the vehicle sprung mass. Defining g cos(φ)/cos(θ) as pseudo gravity, the problem can be equated to a mass on a θ degree hill with a gravity constant of g cos(φ)/cos(θ).

In Figure 2, the current height of C.G. is d sin (θ) + h cos (θ), and the ultimate height of C.G. when the vehicle is at the verge of roll over is $\sqrt{d^2+h^2}$. Therefore, defining the height change of C.G. required for roll over as Δh:

$$\Delta h = \sqrt{d^2 + h^2} - (d \sin\theta + h \cos\theta)$$

$$= \sqrt{d^2+h^2} - \frac{d\, a_{ym} + h\, g \cos\varphi}{\sqrt{g^2\cos^2\varphi + a_{ym}^2}}$$

The minimum amount of potential energy required for roll over is (g cos φ / cos θ) * Δh. Considering that the lateral kinetic energy of a vehicle can be converted to potential energy very quickly through the roll motion, a vehicle has a potential to roll over any time if the lateral energy is larger or equal to the minimum required potential energy, i.e.:

$$\frac{1}{2}V_y^2 > \frac{g\cos\varphi}{\cos\theta}\Delta h$$

$$= \sqrt{g^2\cos^2\varphi + a_{ym}^2}\,\Delta h$$

$$= \sqrt{g^2\cos^2\varphi + a_{ym}^2}\sqrt{d^2+h^2} - (d\, a_{ym} + h\, g\cos\varphi)$$

The lateral velocity V_y can be calculated from longitudinal velocity V_x and vehicle side slip angel β as:

$$V_y = V_x\,\beta$$

[redacted]

Exhibit #1.

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V_x is measured by wheel speed sensors. β is estimated from the measured yaw rate, lateral acceleration, steering wheel angle and vehicle dynamic model. β estimation is a part of the current Yaw Stability Control (YSC) algorithm and the estimation is known to be quite accurate especially on a flat surface.

Motivated by the above inequality condition, a roll over potentiality index Φ_0 is defined as follows:

$$\Phi_0 = \frac{1}{2} | V_x \beta |^2 - \sqrt{g^2 + a_{ym}^2}\sqrt{d^2 + h^2} + d\, a_{ym} + h\, g$$

While defining Φ_0 from the above inequality condition, cos φ is neglected. Roll over detection algorithm is required to detect roll over before the roll angle becomes excessive. When the angle φ is 25 *deg*, cos φ is 0.9, and the effect of neglecting cos φ on Φ_0 is less than 0.4 % of Φ_0. Since this error is mush less than the uncertainties of the vehicle parameters and the estimated vehicle side slip angle, it can be claimed that the effect of the roll angle φ on Φ_0 is negligible.

Positive Φ_0 means that the vehicle has a potential to roll over, and the possibility of roll over increases with Φ_0. Large Φ_0 alone does not mean the vehicle will roll over. The large kinetic energy needs to be converted to the potential energy. It usually happens when a vehicle hits a high mu surface or a bump after a large side slip typically on a low mu surface. When a vehicle hits a high mu surface, the lateral acceleration of the vehicle increases very quickly. In this document, it is assumed that the measured lateral acceleration needs to be more than 80% of statically critical lateral acceleration for roll over to happen. Statically critical lateral acceleration is defined as the acceleration to make a vehicle to roll over statically on a flat surface and described as (d/h)*g.

Out of Φ_0 and measured lateral acceleration, roll over index is defined as follows:

$$\Phi = \Phi_0 \times (| a_{ym} | - \frac{d}{h} g \times 0.8 > 0)$$

The roll over index is roll over potentiality index weighted by the measured acceleration. When the absolute value of the measured lateral acceleration is less then 80% of the critical acceleration, the index is zero. The threshold of the index to trigger roll stability control is yet to be trimmed by simulation and/or field test reflecting the uncertainties of the vehicle parameters and the estimated vehicle side slip angle.

3. Simulation Results

In this section, the feasibility of the defined roll over index is evaluated by simulation using the vehicle model of a full size ban with C.G. height h = 0.84 *m* and half track width d = 0.838 *m*. The forward velocity of the vehicle is around 20 *m/sec*. The environment is a flat high mu surface.

Figure 3 shows the response of a turning maneuver with slowly increasing steering wheel angle. Since the steering wheel angle is increased very slowly, it represents the steady state response of the vehicle.

Figure 4 shows the response of a fish hook type maneuver with very fast steering action from one side to other. The switching point of the steering wheel is determined to maximize the instability of the vehicle roll dynamics.

As the both figures show, the inside wheels of the vehicle are lifted from the ground (Fz = 0) just before the roll angle is increased significantly. The points of the wheel lift match well with the points where the roll over index starts to increase significantly.

Exhibit #1 .

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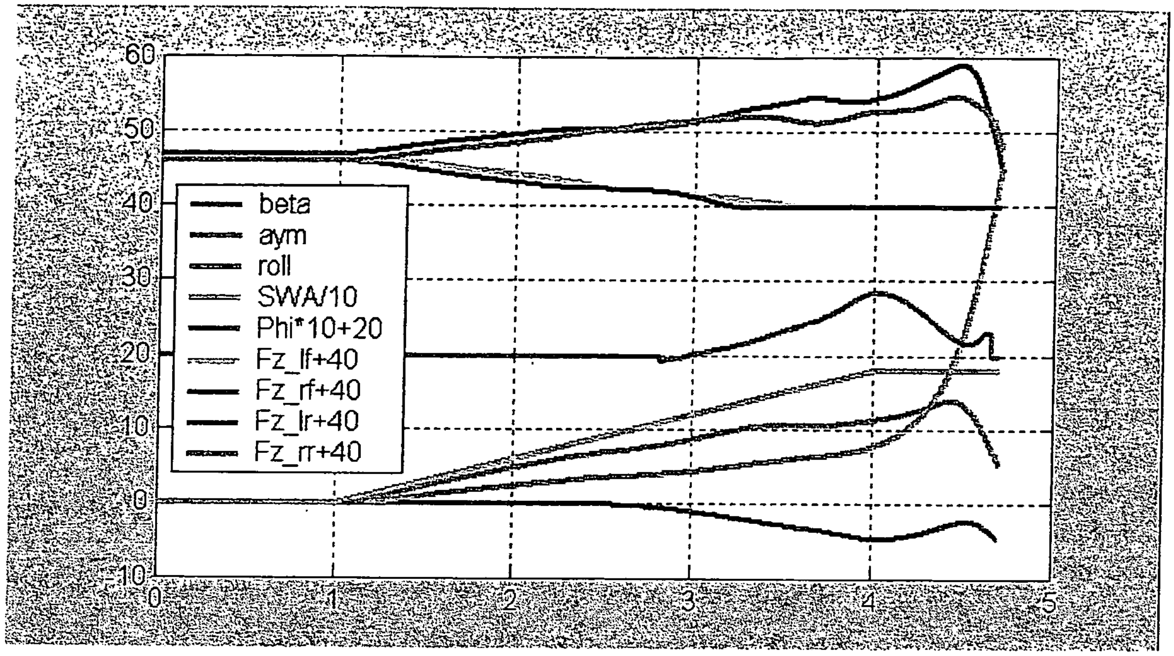

Figure 3. Turning maneuver with slowly increasing steering wheel angle

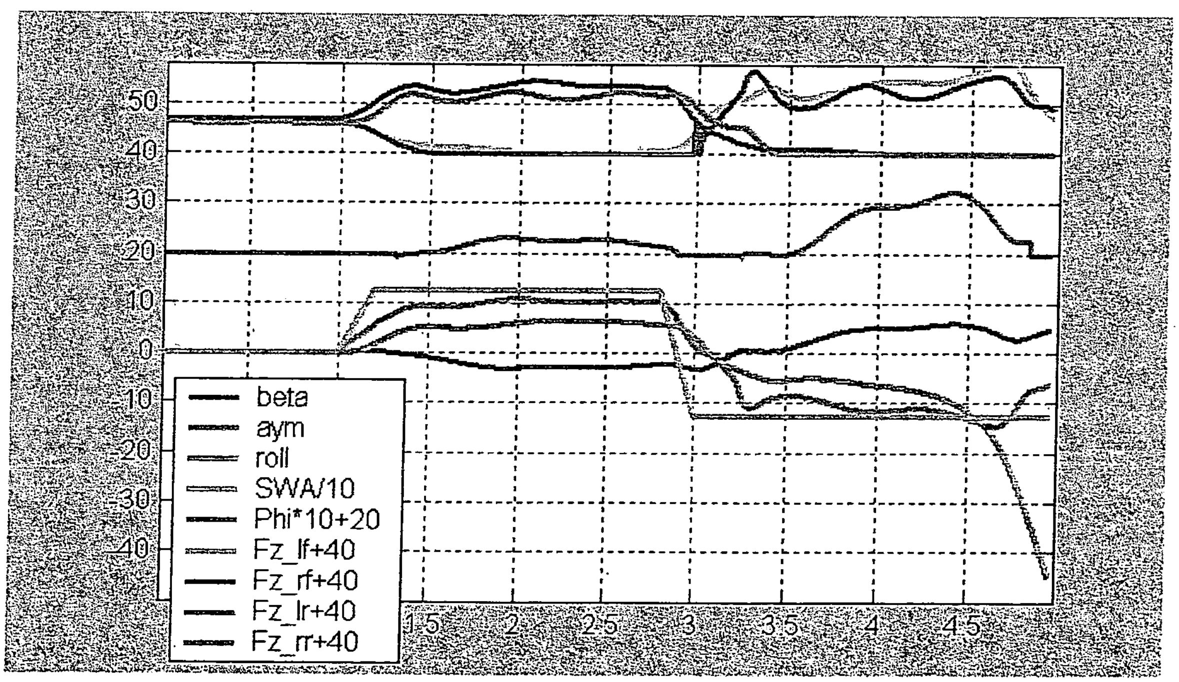

Figure 4. Fish hook maneuver with a fast steering action

4. Conclusions

Exhibit #1.

A new roll over detection algorithm without using roll rate sensor has been developed. The simulation results in several driving conditions show that, the developed roll over index represents the roll over propensitiy fairly accurately. Once if the roll over index reaches a certain threshold, the roll over of a vehicle can be prevented by reducing the vehicle speed through the engine torque intervention or applying brake on individual wheels through VSC actution system. The accuracy of the index needs to be verified by further vehicle testing and/or simulation with more accurate suspension model.

Nomenclature

a_{ym}: measured lateral acceleration
C.G.: center of gravity
d: One half of vehicle track width
Fz: Tire normal load
g: gravity constant
h: nominal C.G. height
SWA: steering wheel angle
V_x: vehicle longitudinal velocity
V_y: vehicle lateral velocity
x, y: sprung mass coordinates
x', y': virtual gravity coordinates
β: vehicle side slip angle
φ: roll angle of vehicle sprung mass
Φ: roll over index
Φ_0: roll over potentiality index

Exhibit #2

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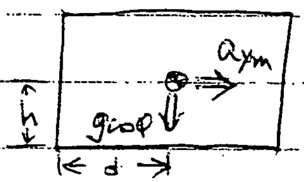
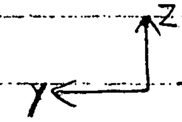
Roll Stability Control

[redacted]

S. Ben Choi



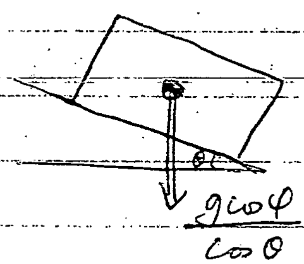


fixed to vehicle

φ : roll angle of sprung mass
a_{ym} : measured Lateral acceleration

$$\tan\theta \triangleq \frac{a_{ym}}{g\cos\varphi}$$

$\Leftrightarrow$



$\Delta h \triangleq$ height change to roll over

$$\Delta h = \sqrt{d^2+h^2} - (d\sin\theta + h\cos\theta)$$

$$= \sqrt{d^2+h^2} - \frac{d\cdot a_{ym} + h\cdot g\cos\varphi}{\sqrt{g^2\cos^2\varphi + a_{ym}^2}} \qquad (\cos 25^\circ = 0.9)$$

potential to roll over if

$$\frac{1}{2}|V_y|^2 = \frac{1}{2}|V_x\beta|^2 > \left(\frac{g\cos\varphi}{\cos\theta}\right)\cdot\Delta h = \sqrt{g^2\cos^2\varphi + a_{ym}^2}\cdot\Delta h$$

$\Leftrightarrow$

$$\frac{1}{2}|V_x\beta|^2 > \sqrt{g^2\cos^2\varphi + a_{ym}^2}\cdot\sqrt{d^2+h^2} - (d\,a_{ym} + hg\cos\varphi)$$

$$\phi_1 \triangleq \frac{1}{2}|V_x\beta|^2 - \sqrt{g^2 + a_{ym}^2}\sqrt{d^2+h^2} + (d\,a_{ym} + hg) \quad \text{positive only}$$

Roll over index ($\triangleq \Phi$)

$$\Phi = \phi_1 * \left(|a_{ym}| - \frac{d}{h}g * 0.7\right) \quad \text{positive only}$$